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An acoustic liner, use of such a liner and method for manufacturing an acoustic liner.

FIELD OF THE INVENTION

The present invention relates to an acoustic liner and the manufacture of such acoustic liner. It also relates to use of said acoustic liner in a hot stream environment, especially in the hot area of an aircraft engine.

BACKGROUND OF THE INVENTION

The noise due to aircraft is of critical concern to communities living around airports. The aircraft engines are the most significant contributors to the total aircraft noise during take-off and landing. The contributing sources of engine noise are fan, compressor, combustor, turbine and jet. It is known to use acoustic liners in the engine inlets of commercial short- medium- and long-range passenger and freight aircraft in order to reduce fan noise. The acoustic liners should preferably be linear since the linear liners are acoustically more efficient than conventional liners as the acoustic characteristics of the linear liners are not sensitive to changing flow and changing sound pressure levels prevailing in the engine ducts. Conventional liners on the other hand have acoustic properties that are extremely sensitive to the flow and sound pressure level.

US-A-6 176 964 describes an acoustic liner employable in jet engine housing construction for sound absorption. The liner has a solid backing sheet having a surface to which is attached a first side of a honeycomb core structure. Attached to the opposing second side of the honeycomb core structure is a mesh structure to which is attached a perforated face sheet to be exposed to the exterior. The acoustic liner is designed to have linear properties while at the same time being durable in order to fulfill the requirements for use as a noise absorber in aircraft engine inlets ("cold stream"). The liner is linear within a narrow frequency band.

US-A-5 175 401 deals with the problem of attenuating a plurality of frequencies using a liner comprising a liner core and a top sheet including a mesh structure. The

problem is intended to be solved by weaving the mesh into a plurality of different determined weave patterns in order to thereby provide a plurality of flow resistances. However, in practice it would be almost impossible to design a weave pattern such that the liner is capable of attenuating a broad frequency band. Further, the liner can not withstand high temperatures, and therefore can not be used in hot stream areas of aircraft engines.

With an increased burden from regulatory authorities to reduce aircraft noise, further developments of more efficient means to reduce engine noise become highly relevant and necessary. As stated above, today there are no linear liners available for use in hot stream areas of aero engines, since current liner technology regarding linear liners for engine intakes ("cold stream") does not meet the thermal and other functional requirements for the engine exhaust areas. The other functional requirements include attenuation of a broad frequency band since the noise in the hot stream areas has a broad frequency spectra. These drawbacks of current liner technology have the effect that the noise environment around airports cannot be improved further as regards hot stream aero engine noise such as combustion noise.

SUMMARY OF THE INVENTION

It is one object of the invention to provide an improved acoustic liner which provides more design flexibility compared to prior art liners in that the ability of optimizing the linear characteristics is improved. It is another object of the present invention to provide a liner which is linear not only with respect to flow variations but also with respect to temperature variations. It is yet another object of the invention to provide a liner which can withstand high temperatures and especially which can be used in hot stream areas of aircraft engines.

Therefore according to one embodiment of the present invention an acoustic liner is provided including a liner core or cavity and a top sheet covering one side of the liner core or cavity facing the environment. The term "acoustic liner" is defined as a liner arranged to absorb sound, i.e. attenuate sound waves. The liner is characterized in that the top sheet comprises a layer of a metallic foam.

In the embodiment with a liner core, the liner core is for example a honeycomb core or a core of metallic foam. The invention is also applicable to liners where the core is substituted with one or more cavities, which can be air-filled. The cavities can be defined by an internal spar- and rib structure. The liner depth determines the frequency of attenuation, wherein a thin liner core provides for attenuation of higher frequencies while a thick liner core provides for attenuation of lower frequencies.

In a preferred embodiment of the invention, the top sheet comprises a perforated sheet in combination with the foam layer. The perforated sheet strengthens the liner. In a case where the foam layer is directly attached to the liner core, a surface of said foam layer opposite the surface facing the liner core can be attached to the perforated sheet. Alternatively the perforated sheet can be sandwiched between the liner core and the foam layer.

The metallic foam alone or in combination with the perforate provides the linear characteristics to the liner. For instance, the foam cell size, cell distribution, degree of open cells, foam density, flow resistance et cetera can be tailored in order to provide a linear liner. A commonly used measure for determining the linear characteristics of a sample with respect to the flow is the so-called non-linearity factor (NLF) that is defined as the ratio of flow resistance at 200 cm/sec and at 20 cm/sec. The non-linearity factor with respect to flow of the inventive acoustic liner is within a range between 1.0 and 3.0 and preferably within a range between 1.0 and 2.5, for example between 1.5 and 2.0.

In accordance with a preferred embodiment of the present invention the foam layer itself or after having been joined to the perforate is compressed for example by using a hydraulic press. The compression of the top sheet is a very effective way of both increasing the acoustic resistance and lowering the non-linearity of the liner with respect to flow variations. However, the compression of the top sheet also lowers the non-linearity of the liner with respect to temperature variations. We herein define a measure of the non-linearity of the liner with respect to temperature variations:

$NLFT = \frac{R_{at\ 500°C}}{R_{at\ 20°C}}$, wherein R is the flow resistance of a sample tested at M=0.35, wherein M is the Mach number.

In order to provide proper linear characteristics with regard to temperature the NLFT (non-linearity factor due to temperature) value should lie within a range between 1 and 1,5. This can be provided also with a not compressed foam layer.

Compression can advantageously be used in designing a liner with variable impedance in the same panel. In practice this means that that the pressure is applied to a different degree in different areas of the sheet, resulting in different acoustic resistance values in the top sheet. The advantage of creating variable impedance over the top sheet is to have a more "broadband" acoustic absorber making the liner more effective in various environments such as different flight conditions for aircraft engines. Compression of the top sheet can be of gradient type or stepped depending on the desired acoustic properties.

The metallic foam can be made of material that can withstand the temperatures of hot stream areas and therefore the acoustic liner is especially adapted for use in hot stream areas. Herein hot stream areas are defined as areas wherein the service temperature is above about 400°C. The liner design does also withstand temperatures below 400°C including temperatures well below freezing, e.g. -55°C. In one application where the acoustic liner is for use in hot stream areas of aircraft engines, i.e. the exhaust areas, the metallic foam is designed to withstand temperatures around 700°C. Accordingly, the metal foam contains a metal or metal alloy having high melting temperature (characteristically about 1400°C-2000°C). Metals which then can be used in the foam comprise Nickel, Titanium and Chromium. The acoustic liner can also be used in other applications with a different service temperature. Then, the metallic foam should be designed for withstanding that temperature and accordingly comprise a suitable metal or metal alloy.

The acoustic liner according to the present invention has a number of advantages over the prior art. Firstly, it can withstand hot stream environments. Further, its three-dimensional structure increases the design freedom and possibility of optimi-

zing the linear properties (acoustic behavior) compared to what is possible with prior art liners. Especially, the developed liner technology allows liner designs with acoustic characteristics that are independent of both flow and temperature. Moreover, the inventive acoustic liner is linear and capable of attenuating sound in a broad frequency band. This is a very important feature of an acoustic liner for use in hot engine exhaust areas, e.g. aircraft engines and other applications wherein the noise has a relatively broad spectra. However, the invention is equally applicable to suppression of noise in cold applications, such as engine inlets. The inventive acoustic liner is light in weight and the cost of manufacture and mounting would be comparable to the costs for liners existing today. Especially the embodiment with a compressed top layer constitutes a very simple and cost-effective way of fine-tuning and optimizing the acoustic liner to a specific application and it allows for using pre-manufactured "off-the shell" top sheets in a variety of applications.

The present invention further includes a use of the acoustic liner in a hot stream environment such as a hot area of an aircraft engine.

The present invention also includes a method of manufacturing an acoustic liner, said method includes the steps of forming a top sheet including a metallic foam layer and having substantially linear characteristics and brazing said top sheet onto one side of a liner core. The steps do not need to be performed in the described order. On the contrary, it may be practical to first braze the top sheet onto the liner core and thereafter design the top surface for proper linear characteristics. In a preferred embodiment the forming of the top sheet includes brazing a perforated sheet onto the foam layer. Further, the acoustic liner can be joined to a backing sheet by brazing, thereby providing a joint that withstand the hot stream environment.

DESCRIPTION OF THE DRAWINGS

Fig 1 shows an example of an acoustic liner according the invention.

Fig 2 shows very schematically an example of a metallic foam sheet according to the present invention.

Fig 3 shows very schematically a side view of another example of a metallic foam sheet according to the present invention.

PREFERRED EMBODIMENTS

In the figure, a panel 1 is shown in the form of an acoustic liner. The panel 1 is designed to withstand hot stream environments and therefore can be used as a noise absorber for example in aircraft engine outlets. The panel also can be used in other hot environments such as in gas turbine applications.

The panel 1 comprises a liner core 2 and a top sheet assembly 5. The core 2 is attached to a solid backing sheet 6, which is impervious. The top sheet assembly 5 includes a layer 3 of a metallic foam and a perforated sheet 4. The liner core 2 is for example a conventional honeycomb core made of Titanium, Nickel or Chromium, or an alloy including one or more of said metals. However, the honeycomb core can be made of any metal or metal alloy withstanding the hot stream environment (typically about 700°C of an aircraft engine). Alternatively, the line core 2 can be made of a metallic foam. Metallic foams will be described more in detail below. The thickness of the liner core 2 determines in which frequency band the panel 1 attenuates sound. A thin core 2 attenuates higher frequencies and a thick core 2 attenuates lower frequencies. A person skilled in the art can by using simple calculations determine a proper thickness of the core in order to attenuate a desired frequency band. The acoustic characteristics of the panel 1 originate from the top sheet assembly 5 and therefore the design of the liner core 2 is not essential except for the thickness of the core, and as long as the core 2 can withstand the hot stream environment.

The metallic foam layer 3 comprises a metal or a metal alloy withstanding the hot stream environment (typically 700° for aircraft engines). For example, Nickel, Titanium or Chromium is chosen for the metallic foam. Alternatively a metal alloy is chosen, for example including Nickel, Titanium and/or Chromium. The metal foam is for example in the order 1-3 mm thick with small, open cells. In accordance with one embodiment all of the cells are open while in an alternative embodiment only a part of the cells are open. The metallic foam layer 3 is brazed to the liner core 2 or

attached to it by means of another method giving an attachment withstanding the 700°C service temperature of the aircraft engine.

The perforated sheet 4 is made of metal, eg Nickel, Titanium or Chromium. The perforated sheet 4 is arranged to strengthen the liner 1. The perforated sheet 4 has non-linear characteristics and its non-linearity is determined by the porosity of the perforate. The perforated sheet 4 is brazed to the metallic foam layer 3 or attached to it by means of another method not clogging the foam and giving an attachment withstanding the 700°C service temperature of the aircraft engine.

The linearity of the acoustic liner is determined by the linear characteristics of the top layer assembly 5; the liner core has, as discussed above, practically no influence on the linearity of the liner. A linear liner has a linear behavior both with respect to flow variations and with respect to temperature variations. However traditionally linearity considerations have been focused on the first mentioned aspect. A measure of a non-linearity factor (NLF) with respect to flow variations is defined as

$NLF = \frac{R_{at200cm/\sec}}{R_{at20cm/\sec}}$, wherein R is the flow resistance of a sample tested.

An ideal linear liner has a NLF value of 1. The foam has a resistance to air flow which can be optimized by fine-tuning for example the cell size and the density of the metallic foam in order to achieve a substantially linear liner. By performing flow resistance tests on samples and modifying the samples in accordance with the results, a top sheet assembly 5 can be developed having a NLF value close to 1, for example in the range 1.5 – 2.0. The non-linear characteristics of the perforated sheet is compensated by the design flexibility of the metallic foam material. In the testing, the characteristics of perforated sheet samples could be tested separately and the characteristics of metallic foam layer samples could be tested separately. The characteristics of a tested foam layer sample and a tested perforated sheet sample can thereafter be superposed in order to obtain the characteristics of a potential top sheet assembly. The brazing of the perforated sheet onto the metallic foam layer has no effect on the acoustic properties of the liner.

The linear behavior with respect to temperature variations can be optimized by compressing the top sheet assembly. We herein define a measure of the non-linearity of the liner with respect to temperature variations:

$NLFT = \frac{R_{at\,500°C}}{R_{at\,20°C}}$, wherein R is the flow resistance of a sample tested at M=0,35, wherein M is the Mach number.

In order to provide proper linear characteristics with regard to temperature the NLFT value should lie within a range between 1 and 1,5.

The compressed top sheet assembly 5 can be manufactured by applying a pressure on an "off the shelf" metallic foam sheet and the perforated top sheet 1 using a conventional press. The linear characteristics of the top sheet assembly are tested by making temperature resistance tests as described above and the pressing process is repeated until the top sheet assembly has desired linear characteristics. The compressed top sheet 5 also provides for an increased acoustic resistance.

In fig 2, the top sheet assembly 5 is divided into areas 5a, 5b, 5c, 5d, wherein a different pressure has been applied to the different areas. In this way, a top sheet assembly can be provided having desired characteristics for a broader frequency band.

In fig 3, the top sheet assembly has been manufactured by applying a pressure continuously changing over the sheet.

The herein described top sheet assembly 5 includes the metallic foam layer 3 and the perforated sheet 4. However, an acoustic liner with desired characteristics could be achieved even without the perforated sheet. Further, in the herein described example the metallic foam layer 3 of the top sheet assembly is joined to the liner core 2 while the perforated sheet 4 faces the environment. This arrangement provides a durable

liner. Alternatively, the perforated sheet 4 can be joined to the liner core and the metallic foam layer 3 arranged on the opposite side of the perforated sheet.